PERFORMANCE MEASURES FOR DISMOUNTED WARRIOR ENCAPSULATION EFFECTS

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ABSTRACT

Research regarding the effects of encapsulation on soldier performance is critical for achieving effective mission performance as well as the survivability capabilities of dismounted soldiers of the Future Force. Soldier encapsulation is defined as enclosing the soldier's body in such a manner that all skin is protected from exposure to the elements of the battlefield. The objective of this research is to identify the effects of encapsulation on mission performance and to develop methods for further research on encapsulation effects of Future Force soldier systems. This research investigated the effects of three equipment configurations (baseline and two encapsulation configurations) on soldier performance during three mission related scenarios. Encapsulation effects on soldier's cognitive functioning and stress perceptions are discussed here. The characterization of cognitive performance and psychological state during military operations affords better understanding of human performance capabilities and opportunities to find predictors of future performance effectiveness.

1. INTRODUCTION

The U. S. Army has a limited amount of research and data regarding the performance effects of encapsulation. These data are critical to achieving effective mission performance as well as the survivability capabilities of future dismounted soldiers of the Future Force. Soldier encapsulation is defined as enclosing the soldier's body in such a manner that all skin is protected from exposure to the elements of the battlefield. Although research has been conducted on individual items of combat equipment and various components of dismounted soldier systems, very little performance-based research has been conducted using a systems approach to validate soldier-equipment compatibility. For example: the integration of the protective mask, chemical protective clothing to include gloves, boots and individual combat equipment is required when soldiers are operating in a suspected contaminated environment. The integration of an encapsulation ensemble, including laser, ballistic, nuclear, biological and chemical (NBC), and climatic protection is a requirement of the Future Force Warrior concept. The objective of this research is to identify the effects of encapsulation on mission performance and to develop methods for further research on encapsulation effects of Future Force soldier systems. The characterization of performance and psychological state during military operations affords better understanding of human performance capabilities and opportunities to find predictors of future performance effectiveness. The U. S. Army Research Laboratory's (ARL) Cognitive Readiness program focuses on developing methods that reliably measure soldier stress and cognitive processing and to assess these effects on soldier performance.

2. METHOD

2.1 Participants

Twelve U.S. Army infantry soldiers (11 series MOS) served as volunteer participants for this experiment. The research participants ranged in age from 20 to 35 years (mean = 23.8 years) with approximately 2 to 10 years in service (mean = 3.1 years). Participants were physically fit, had infantry tactical experience, and normal vision and hearing. Participants were tested wearing three equipment configurations: baseline configuration (no encapsulation) using the Personal Armor System Ground Troops (PASGT helmet and vest; current encapsulation configuration, using the M40 mask and PASGT helmet and vest; and Land Warrior encapsulation configuration, using the M45 mask and the Joint Service Lightweight Integrated Technology (JSLIST), Modular Integrated Communications Helmet (MICH), and interceptor outer tactical vest (Figure 1).

Figure 1. Equipment configurations (from left to right: baseline; current; and Land Warrior equipment configurations)

2.2 Familiarization and Training

There was a total of nine test days. The first three days were training days for familiarization and practice. This was followed by six test days. Each participant was

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tested in each equipment configuration twice. Participants wore an equipment configuration each day, cognitive battery and taken on a familiarization march through the cross-country and obstacle courses. During this time, a demonstration was conducted to illustrate the proper procedures on how to safely negotiate the obstacles. After the initial march, each research participant practiced negotiating the obstacle course twice. The soldiers participated in training during the second and third days of the investigation. Research participants were administered a cognitive battery test followed by stress assessment questionnaires. They negotiated the cross-country course, obstacle course, and conducted live-fire excises daily.

2.3 Scenarios

Participants wore each equipment configuration while performing mission related tasks that included a cross country course, obstacle course, and weapon firing. These test courses and ranges are located at Aberdeen Proving Ground, MD.

2.3.1 Cross Country Course

The cross-country course is a 4 km path through woods and is designed to simulate dismounted warrior movements executed during a “movement to contact” mission. The course consisted of two segments along a path through the woods forming a loop. The terrain is generally flat and the path is unobstructed in places, but elsewhere crosses marshes, thick foliage, and fallen trees. To investigate individual performance measures, an array of 24 wooden silhouette targets was assembled. Eight targets were presented on the course the first three days and 16 targets were presented on the course the last six days. The targets were counterbalanced from left to right at 15 to 30 meter intervals from the center of the course path and spaced 80 meters apart over the length of the course. The target location was changed for each mission to minimize learning effects. An additional cognitive load, a “Call-sign Acquisition Test,” was presented using an MP3 digital audio player with built-in loudspeakers.

2.3.2 Obstacle Course

The 500-meter obstacle course consists of 20 individual obstacles spread over a serpentine course. Obstacles were chosen to subject the participants to maneuvers executed during an assault mission task in combat. Thirteen of the obstacles were equipped with electronic pressure pads so the research participants' beginning and ending times were recorded. A data acquisition system receives signals from the pads and computes total course and individual obstacle times. The course design is one that requires soldiers to alternate between load carriage methods to negotiate the various counterbalanced across days. During the first familiarization day the soldiers were administered a obstacles (i.e., switch from shoulder slung carry to hand carry, etc.). The course design requires the research participants to use most of their muscle groups while managing the load carried from varying body postures. The maneuvers they perform in the course are similar to those in an assault mission, such as running, jumping, climbing, balancing, negotiating buildings, stairs, windows, and crawling.

2.3.3 Live Firing

Live-fire testing was conducted at M-Range. This is an outdoor small arms research facility that is subdivided into four firing lanes (A, B, C, and D lanes). Each lane is designed to present targets to a single shooter, located at a fixed firing position, at ranges of 50, 75, 100, 150, 200, 250, 300, 400, 500, and 550 meters. The range is designed with four identical firing lanes with a firing station or bunker for each lane.

The targets used at M-Range are Olive Drab (O.D.) "E" type silhouette targets. Targets contain foam inserts sandwiched between two thin sheets of aluminum. The aluminum sheets are wired to electronic sensors. These targets are attached to target holding mechanisms, which are in turn wired to a command and control center containing a computer-linked target controller. The target controller and software are capable of presenting an array of targets (programmed) on each lane in any sequence and for any time interval, as well as recording the results.

Hits are registered when a copper-jacketed projectile pierces the front aluminum sheet, passes through the foam, and touches the rear aluminum sheet, completing the circuit between the two sheets. When the circuit is completed, the system electronically registers and records a hit and simultaneously lowers the target. The equipment is capable of electronically recording: shooter identification, target range, target exposure time, time to fire each round, number of rounds fired, which round hit the target and total number of targets hit. All targets were presented for a time of five seconds with a three-second interval between target exposal.

2.4 Cognitive Performance and Stress Assessment

The Cognitive Performance Assessment for Stress and Endurance (CPASE) (Mullins, 2002), the Multiple Affect Adjective Check List – Revised **(**MAACL-R) (Lubin & Zuckerman, 1999), the Subjective Stress Scale (SUBJ) (Kerle & Bialek, 1958) and the Specific Rating of Events (SRE) (Fatkin, King, & Hudgens, 1990) were completed each morning (pre-measure) and following the cross country course, obstacle course, and weapon firing (post-measures). Test data were collected for six days.

Participants wore each equipment configuration for two repetitions, counterbalanced across days.

2.4.1 Cognitive Performance Assessment for Stress and Endurance (CPASE)

The 6-minute CPASE examines aspects of short-term memory, logical reasoning, calculation, perception, and spatial processing. These correspond to military operational tasks such as map reading, navigation, communications, operations, and decision making. This is a paper and pencil battery that is amenable to use in field settings. There are sixty versions available for use in repeated measure experiments.

This assessment was administered as a test booklet, containing four timed tests: Verbal Memory, Logical Reasoning Addition, and Spatial Manipulation. Participants were provided with three practice sessions to become familiar with the test battery, and to decrease influences of the learning effect (Baddeley, 1968).

Verbal Memory. Short-term memory is tested using lists taken from a word usage text (Thorndike & Lorge, 1944). Each list consists of twelve one or two syllable words with the most common usage rating (100 or more per million). Research participants have one minute to study the list and one minute for recall.

Logical Reasoning. This reasoning test evaluated the research participants' understanding of grammatical transformations on sentences of various levels of syntactic complexity (Baddeley, 1968). Each item consists of a true/false statement such as 'A follows B----AB' (false) or 'B precedes A----BA' (true). The test is balanced for the following conditions: positive vs. negative, active vs. passive, precedes vs. follows, order of statement letter presentation, and order of letters in letter pair (equivalent to balancing for true/false). Letter pairs are selected to minimize acoustic and verbal confusion. Research participants have one minute to complete as many of the 32 items as possible.

Addition. This task, adapted from Williams & Lubin (1967), is used to test working memory. Each item consists of a pair of three-digit numbers that were selected from a random number table. The task is subject paced. Research participants have thirty seconds to complete as many of the fifteen problems as possible.

Spatial Manipulation. Spatial skills are tested using a mental rotation task adapted from Shepherd's work (1978). A six-by-six grid is enclosed within a hexagon measuring 2.8 centimeters. Areas of the grid are filled in to create random patterns. To the right of each test pattern are three similar patterns. One of the three patterns is identical to the test pattern except that it has been rotated. The task is to select this pattern. Each test consists of eighteen items balanced for the number of grids filled in (7, 9, or 11), pattern density (adjacent blocks filled in vs. one break between pattern blocks), and rotation of the correct answer (90, 180, 270 degrees). Research participants have two minutes to complete as many of the items as possible.

2.4.2 Stress Assessment

Multiple Affect Adjective Check List – Revised (MAACL-R) The MAACL-R (Zuckerman & Lubin, 1985) was administered to assess the individual's situational stress perception measure. It consists of five primary sub-scales (Anxiety, Depression, Hostility, Positive Affect, and Sensation Seeking) derived from a one-page list of 132 adjectives. An overall distress score, Dysphoria is calculated from the Anxiety, Depression, and Hostility scores. The form is completed within one to two minutes, and provides critical information regarding the dynamics of the stress experienced by the respondents. Each sub-scale score indicates the level or intensity of the stress response, as well as the primary stress components contributing to that response. Knowledge of the specific stress components at work is necessary for the interpretation of stress perceptions and assists in a more appropriate assignment of effective countermeasures needed to potentially enhance performance.

Subjective Stress Scale The Subjective Stress Scale (SUBJ; Kerle & Bialek, 1958) detects significant affective changes in stressful conditions. Subjects are instructed to select one word, from a list of 15 adjectives that best describes how you "feel right now" or "how they have felt during a specific time point during the study". This form is administered in conjunction with the MAACL-R and the SRE. It takes less than a minute to administer.

Specific Rating of Events The Specific Rating of Events (SRE; Fatkin, King, & Hudgens, 1990), allows participants to rate (on a scale of 0-100) how much stress they have experienced during a specific period of time during the study. This form is administered in conjunction with the MAACL-R and the SUBJ. It takes less than a minute to administer.

3. RESULTS AND DISCUSSION

3.1 Cognitive Results

Cognitive performance tasks included verbal memory, logical reasoning, addition, and spatial rotation. To delineate performance differences each test was evaluated as to the number of items completed correctly. A separate session (pre/post) by equipment configuration (baseline, current, Land Warrior) by repetition (trial 1,

trial 2) repeated measure analysis of variance (ANOVA) was computed for each performance variable and each of the following operational missions; cross country, obstacle course, and weapons firing. A criterion level of $p \leq 0.05$ for significance was employed throughout the analysis. Pos-hoc comparisons were also made for significant results through Tukey's Honestly Significant Differences (HSD) Test.

3.1.1 Encapsulation Effects

There were no significant encapsulation effects for post obstacle course or post live-fire testing. Significant post cross country encapsulation effects were found for three of the four cognitive tests: logical reasoning ($F(2,22)=6.71$;$p=.005$), addition ($F(2,22)=4.19$;$p=.03$), and spatial manipulation ($F(2,22)=5.55$;$p=.01$). Logical reasoning had a significant decline in performance from baseline (M=14.0), with lower scores for current (M=11.5; 18% decline) and Land Warrior (M=12.0; 14% decline) configurations (Figure 2). The baseline (M=8.5) measure for addition was significantly different from the Land Warrior configuration (M=6.9; 19% decline) (Figure 3). Spatial manipulation had a significant decline in performance for the Land Warrior (M=13.6) from the baseline (M=15.5) and current (M=14.6) configurations (12% and 7% decline respectively) (Figure 4).

These performance decrements could have a significant impact on military operations. Other research has also indicated that exercise while wearing chemical protective clothing (CPC) produces significant declines in cognitive performance (Williams, Englund, Sucec, & Overson, 1997). For logical reasoning they found exercise participants wearing CPC had more lapses and worked at a slower pace. Performance declines were also found for addition and spatial tasks.

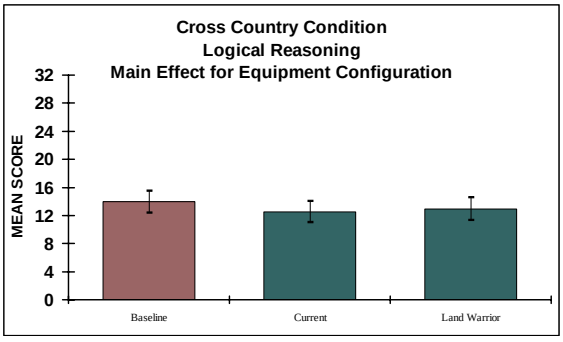

Figure 2. Logical Reasoning, Main Effect for Equipment Configuration

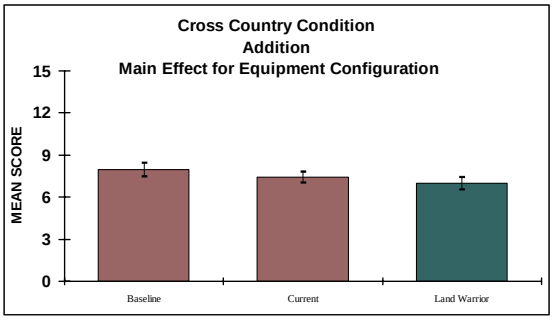

Figure 3. Addition Main Effect, for Equipment Configuration

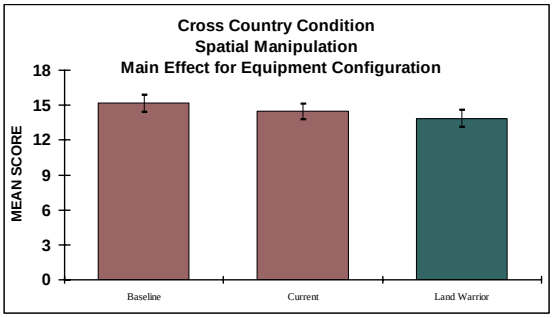

Figure 4. Spatial Manipulation, Main Effect for Equipment Configuration

3.1.2 Session Effects

For Verbal Memory significant main effects were found between the pre and post measures for cross country ($F(1, 11) = 19.12$; $p= .001$) and the obstacle course ($F(1, 11) = 16.64$; $= .002$). Participants performed slightly higher on the pre-test condition. The mean for the pre measure was 7.35, the post cross country was 6.39, and the post obstacle course was 6.40.

There were significant main effects for the logical reasoning task between the pre and post measures for cross country ($F(1, 11) = 6.13$; $p= .03$), the obstacle course ($F(1, 11) = 3.29$; $p= .01$), and the weapon firing ($F(1, 11) = 14.91$; $p= .003$). Participants performed slightly higher on the pre-test condition. The mean for the pre measure was 13.78, the post cross country was 12.53, the post obstacle course was 12.75, and the post weapon firing was 12.21.

For the logical reasoning task, cross country condition there was a significant interaction for session (pre, post) and equipment configuration ($F(2, 22) = 3.60$;

p= .05). Performance while wearing the baseline configuration was higher then either of the encapsulation configurations, with the following means: baseline mean 13.94, current mean 12.56, and Land Warrior mean 12.96 (baseline vs. current p = .005: baseline vs. Land Warrior p= .006). For the pre-post by equipment configuration there was a slight decline in performance from baseline for the encapsulation configurations.

For the addition task, obstacle course condition there were significant main effects for session (pre post) (F (1, 11) = 6.45; p= .03). Performance was higher for the post measure (pre mean = 7.31; post mean = 7.85). This effect is most likely due to practice. This is consistent with other findings. Williams and Lubin (1967) found the addition task to be especially susceptible to practice.

3.2 Stress Assessment Results

A four-way multivariate analysis of variance (MANOVA), repetitions (2) by equipment configuration by session (pre, cross country, obstacle course and live fire) by measure (anxiety, depression, etc.), was computed. Separate analyses were computed for the MAACL-R, SUBJ, and SRE. In these analyses, configuration was a between-subjects factor; repetition, equipment configuration, and measure were within-subjects factors. A criterion level of $p \leq 0.05$ for significance was employed throughout the analyses. The homogeneity of variance assumption for these analyses was first tested for confirmation. If this assumption was not met, the Greenhouse-Geiser correction was applied before significance was determined. Post-hoc comparisons were also made for significant results through Bonferroni's Test or Tukey's Honestly Significant Differences (HSD) Test.

3.2.1 Encapsulation Analysis

A multivariate analysis of variance (MANOVA) was conducted on the MAACL-R stress perception data. There were significant main effects for measure (Wilks' λ = .027; F (5,7) = 50.191; p = .000) and equipment configuration (Wilks' λ = .419; F (2,10) = 6.919; p = .013). Main effects were not found for repetition (Wilks' λ = .761; F (1,11) = 3.454; p = .090) or Session (Wilks' λ = .667; F (3,9) = 1.495; p = .281). When the analysis results were not significant the data were pooled; data were collapsed across repetition and session. This pooling of the data left one measure of each subscale for each condition. Once the data were collapsed, paired 2-tail t-tests were used to determine exactly where the significant differences occurred within each subscale and in which condition.

For Anxiety, participants reported significantly lower levels of uncertainty in the current configuration than during the baseline configuration (t (11) = -2.872, p < .05). Participants reported significantly higher levels of depression or a sense of failure during the current and Land Warrior configurations when compared to the baseline configuration (t (11) = -2.96, p < .05; t (11) = -3.037, p <.05). For Hostility, participants reported higher levels of frustration during both encapsulation configurations then reported in the baseline configuration (t (11) = -2.56, p < .05; t (11) = -4.15, p < .01).

In this study participants demonstrated significant differences in MAACL-R stress levels caused by wearing different ensembles. The MAACL-R stress levels were comparable to the results of other encapsulation studies that used these measures, such as testing at the Chemical Defense Testing Facility (CDTF) at Fort Mc Clellan, Alabama and patient decontamination scenarios. Anxiety levels demonstrate that these soldiers were confident in their ability to perform their duties. Hostility levels were higher during encapsulation which demonstrates levels of frustration. These frustration levels may be due to the different weights and comfort of each ensemble. In general, although the sessions included in this research effort showed differences in stress levels, these levels were not high enough to degrade performance.

3.2.2 Comparative Stress Data

The stress assessment battery used in this research has been used extensively in other research areas. This allows for a direct comparison between data collected during this project and data collected in other test environments. In order to put these stress levels into perspective, results were compared with other research efforts involving encapsulation. The groups include: soldiers performing patient litter decontamination (Patient Decon), where the participants wore MOPP4 and had to perform during day operations; chemical decontamination training facility (CDTF) students in six hours of MOPP4 training to decontaminate weapons and vehicles in a live agent environment; and Special Forces Assessment and Selection (SFAS) participants in training to be selected for a Special Forces assignment. At time points during this research effort, participants did demonstrate significant differences caused by wearing different ensembles (current and Land Warrior). However, in many cases, these were not significantly different from other encapsulated, high stress situations (Patient Decon and CDTF).

The SUBJ and SRE questionnaires demonstrated a better sensitivity to the amount of stress the participants were feeling. It may be due to the fact that these are global stress questionnaires. The MAACL-R showed sensitivity between encapsulation ensembles and indicated no significant differences among the tasks. Anxiety levels that are significantly lower than other

encapsulation research efforts demonstrate that these soldiers were confident in their ability to perform the duties required of them. Hostility levels were reported higher during encapsulation which demonstrates levels of frustration. These frustration levels may be due to the different weights and comfort of each ensemble. These levels of frustration are comparable to the other comparative military relevant research particularly when new equipment is being researched. During the obstacle course portion, the SUBJ ratings are significantly higher for soldiers wearing the Land Warrior configuration than for those wearing the baseline, or during the SFAS and the CDTF training. This is most likely due to the mask and it fitting properly. Both encapsulation configurations are more stressful than the baseline during the cross country. This is due to the ensemble itself. There are weight issues, mask issues and the terrain to deal with during this scenario. During the live fire exercise, soldiers reported significantly lower SRE and SUBJ ratings than the other military scenarios. This is believed to be associated with the actual event itself. Soldiers have a desire to fire live ammunition. Previous research using psychological and physiological measures conducted on this live-fire range (Fatkin, Hudgens, Torre, King, & Chatterton, 1991) has shown that testosterone levels are high and vigor and vigilance reign. Their stress levels across the board are lower during the live fire scenario.

In general, although the various sessions included in this research effort (such as, negotiating the cross country and obstacle courses) showed differences in stress levels, these levels were not high enough to degrade their performance times to complete their tasks. Based on previous research, donning encapsulation ensembles is stressful in and of itself and we know that First Responders are considered a high stress profession (Fatkin, 1998; Fatkin, 2003; Headley, 1997). These professionals are required to wear encapsulated systems for varying durations of time and under uncertain conditions. Even with the proper training, experience, and sufficient practice, these professionals demonstrate delayed stress effects, surfacing later, after a period of no apparent symptoms. Some stress response symptoms to critical incidents are headaches, nightmares, fatigue, or poor concentration. These effects can last for a few weeks or accumulate over time.

4. CONCLUSIONS

The encapsulation system can create at least two sources of poor performance. First, this occurs for the individual configurations, where data are required to assess relative contribution and location of “high-error” components. Second, and at least as important if somewhat more complex to assess, it also occurs for the entire encapsulated system (encapsulation, weapons, and other subsystems). There is no other way to determine either positive or negative interactive effects among configurations, such as the joint effects of gloves (potential to restrict tactile feedback), clothing (binding at body joints can prohibit natural or comfortable posture), and vision protection (can prohibit quick and clear target sighting, identification friend or foe, etc.). Given that battlefield encapsulation conditions are becoming increasingly necessary, it is important for safety and survivability, that the overall system performance be assessed in the aggregate.

The cognitive and stress assessment measures used in this research are sensitive to changes in equipment configuration and may be used to identify the effects of encapsulation on mission performance. This methodology provides a quick effective way to measure performance changes related to equipment configurations and operational tasks.

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